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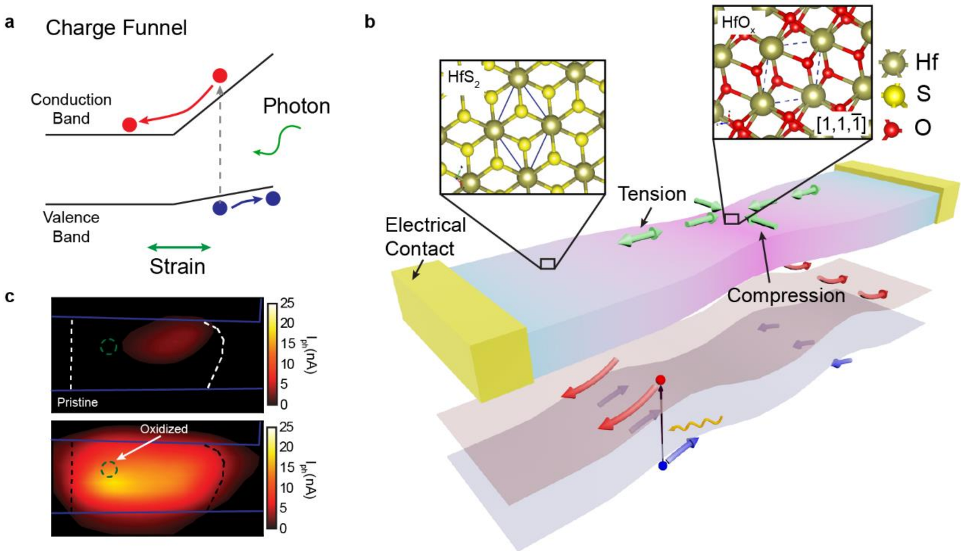
Laser-irradiated 2D materials: a new path towards straintronic devices

Graphene and transition metal dichalcogenides (TMDs) offer a unique platform to enable novel opto-electronic devices. Thanks to their peculiar physical and electronic properties such as bandgap tuneability, chemical functionalisation and the ability to sustain high levels of strain, such materials can enable flexible photodetectors, highly-efficient solar cells and unforeseen "straintronic" devices, i.e. devices which electronic properties are tuned by strain. Laser-irradiation can be used to modify the properties of 2D materials to enable new devices. Using this technique, we are able to define photoactive junctions in functionalised graphene which display an unprecedented linear dynamic range of 44 dB. This is achieved through the efficient quenching of hot-carrier effects in graphene and demonstrates the first purely photovoltaic graphene-based photodetector [1,2]. Laser-irradiation is then used to induce photo-oxidation in ultra-thin HfS2. In this way, a spatially varying bandgap can be engineered using a local strain field to enable the first observation of the so-called "inverse charge-funnelling" [3], as illustrated in Figure 1. This effect allows photo-excited charges to be driven away from the excitation area, towards regions of smaller gap, where they can be efficiently separated and collected. We observe an enhanced signal, with a 350 % improvement in the responsivity with respect to the pristine device, indicating efficient extraction of photogenerated carriers. The bias dependence of the photocurrent demonstrates that the measured signal is due to the inverse charge-funnelling enabled by the strain-engineered gradient of energy gap in the planar HfS2/HfO2 interface. Strain-engineering in 2D materials represents a new field with promising applications for a new generation of electronic devices, in particular when applied to superlattice heterostructures [4].

References

[1] De Sanctis A. et al., Science Advances 3, e1602617 (2017)
[2] De Sanctis A. et al., Materials 11, 1762 (2018)
[3] De Sanctis A. et al., Nature Communications 9, 1652 (2018)
[4] De Sanctis A. et al., arXiv:1810.03903v2 (2018)

Figures



Fgure 1: a) Charge-funnel concept. b) Selective oxidation lead to lattice mismatch at the interface between HfS2 and HfOx creating a strain gradient which modulates the bandgap. c) Enhanced photoresponse is observed in proximity of the oxidised area as a result of charge-funnelling.